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The Exciting World of Microcalorimetry

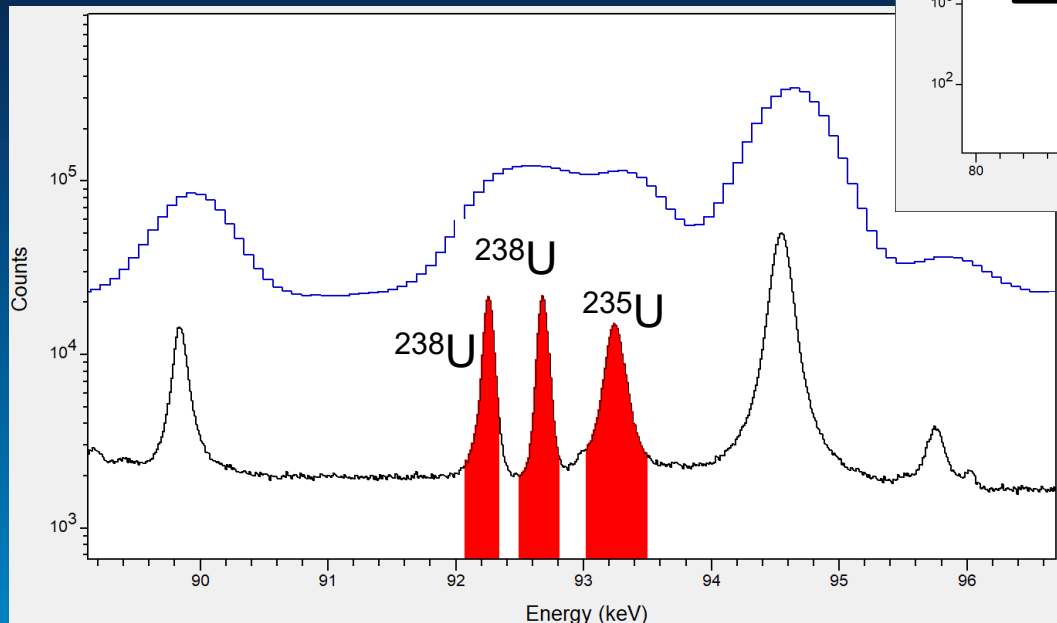
Shannon Kossmann

7 March 2019

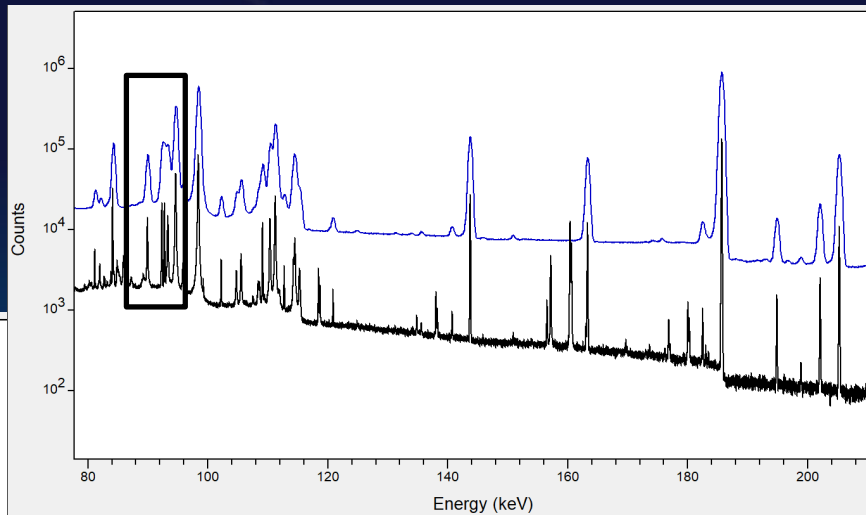
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Exciting World of Microcalorimetry

Enriched Uranium, ~10%
(A1-324)



Spectrum from Mike Yoho



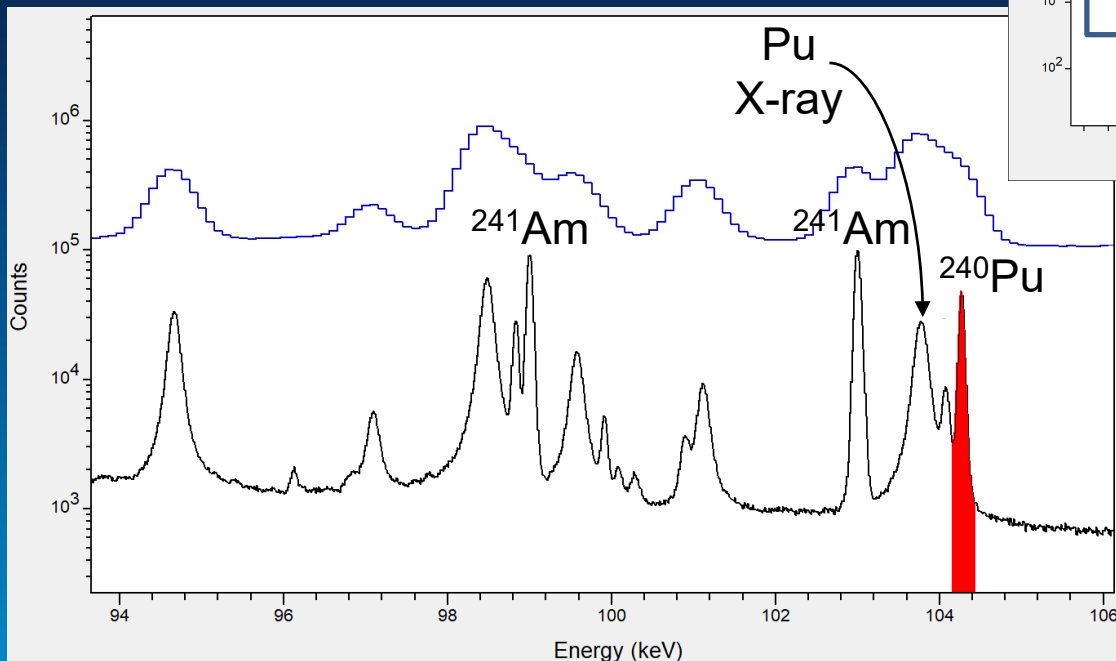
Spectrum from Mike Yoho

Microcalorimeter gamma spectroscopy allows for resolution of peaks important for isotopic analysis

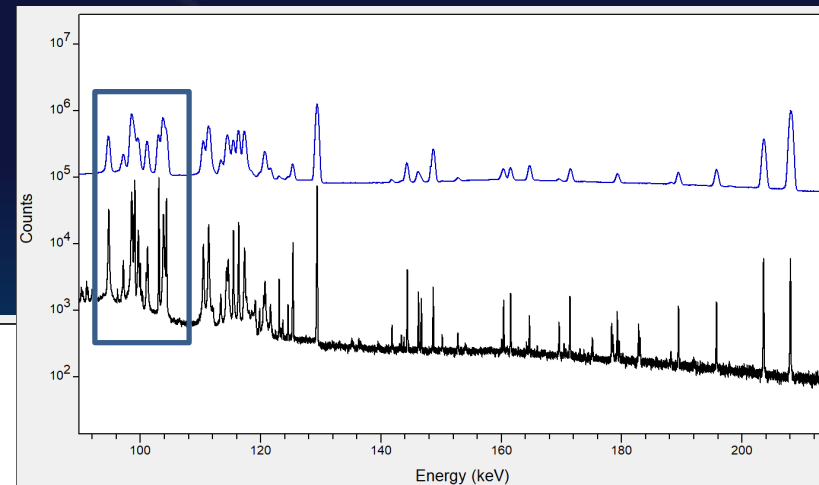
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Exciting World of Microcalorimetry

Low-burnup plutonium,
~6% ^{240}Pu (PIDIE 6-1)



Spectrum from Mike Yoho



Spectrum from Mike Yoho

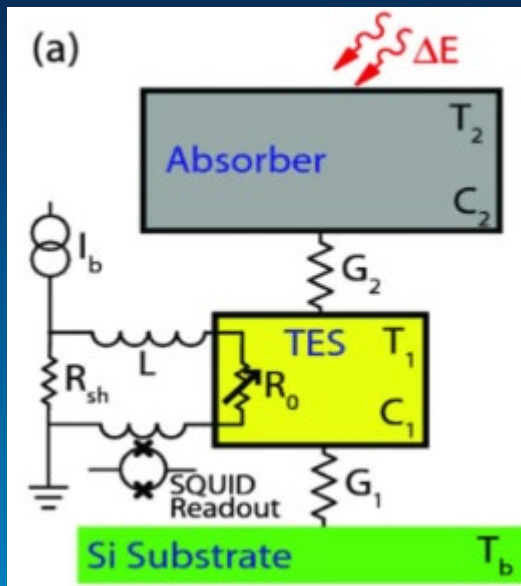
Microcalorimeter gamma spectroscopy allows for resolution of peaks important for isotopic analysis

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Some Basics

Microcalorimeters
measure changes in
energy as a change in
temperature

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$
- $E = C \times \Delta T$



<https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-16-26714>

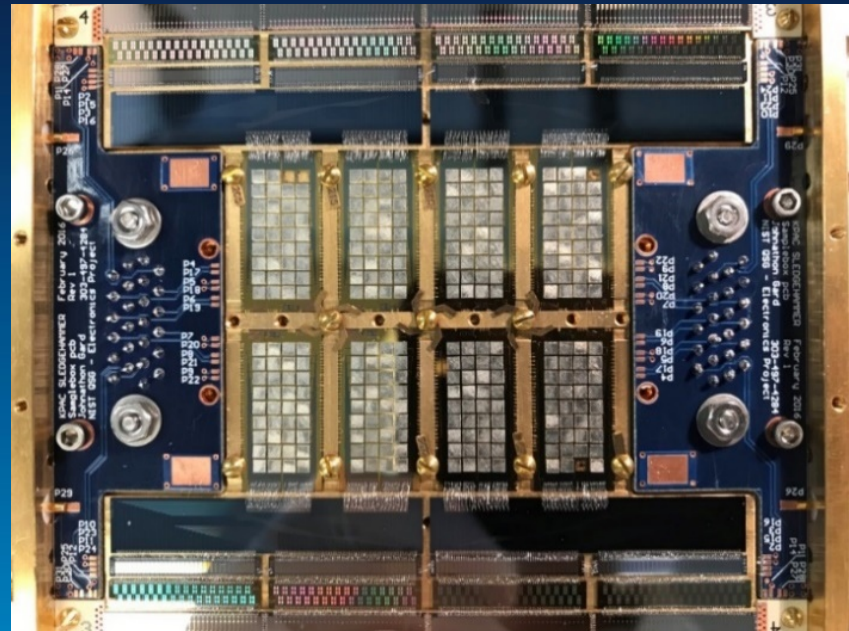


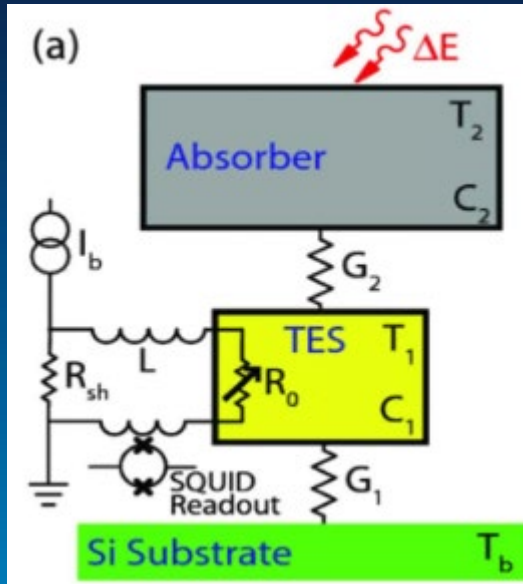
Photo credit: Mark Croce

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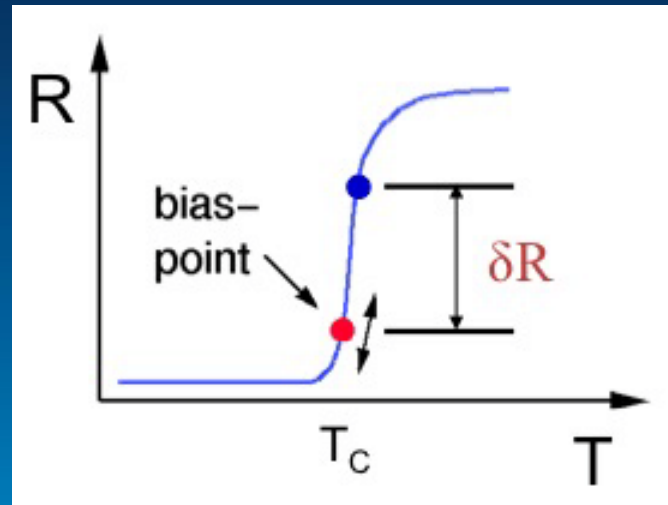
Some Basics

■ $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$

Transition-Edge Sensors register a small change in temperature as a measurable change in resistance



<https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-16-26714>

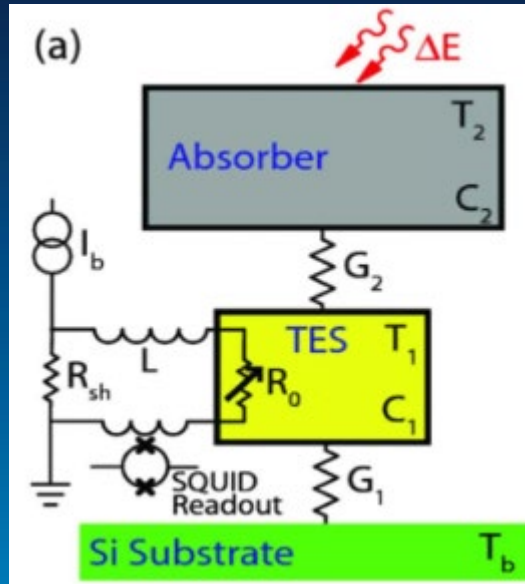


https://www.researchgate.net/figure/Illustrative-plot-of-resistance-vs-temperature-for-a-superconductor-The-transition-is_fig4_228440334

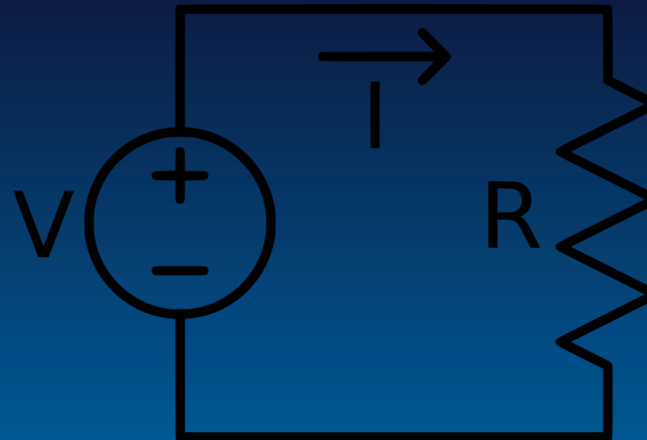
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Some Basics

- $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$



<https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-16-26714>



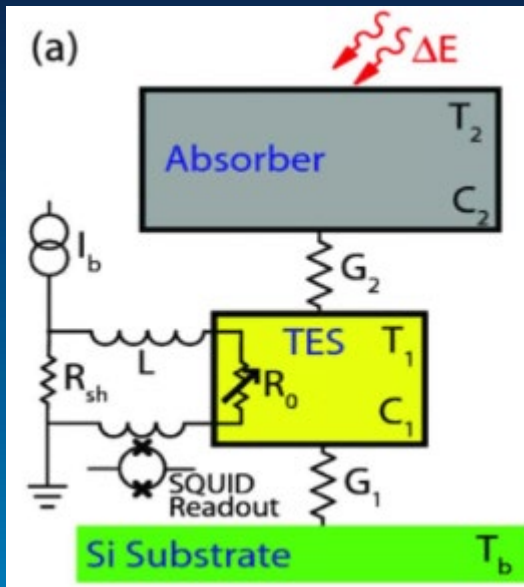
https://commons.wikimedia.org/wiki/File:Ohms_law_voltage_source.svg

By Ohm's Law with a constant voltage and a change in resistance, the current must change

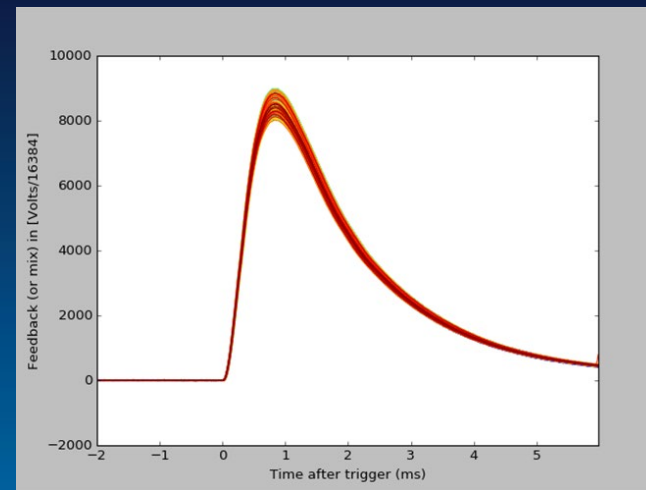
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Some Basics

■ $\Delta E \rightarrow \Delta T \rightarrow \Delta R \rightarrow \Delta I$



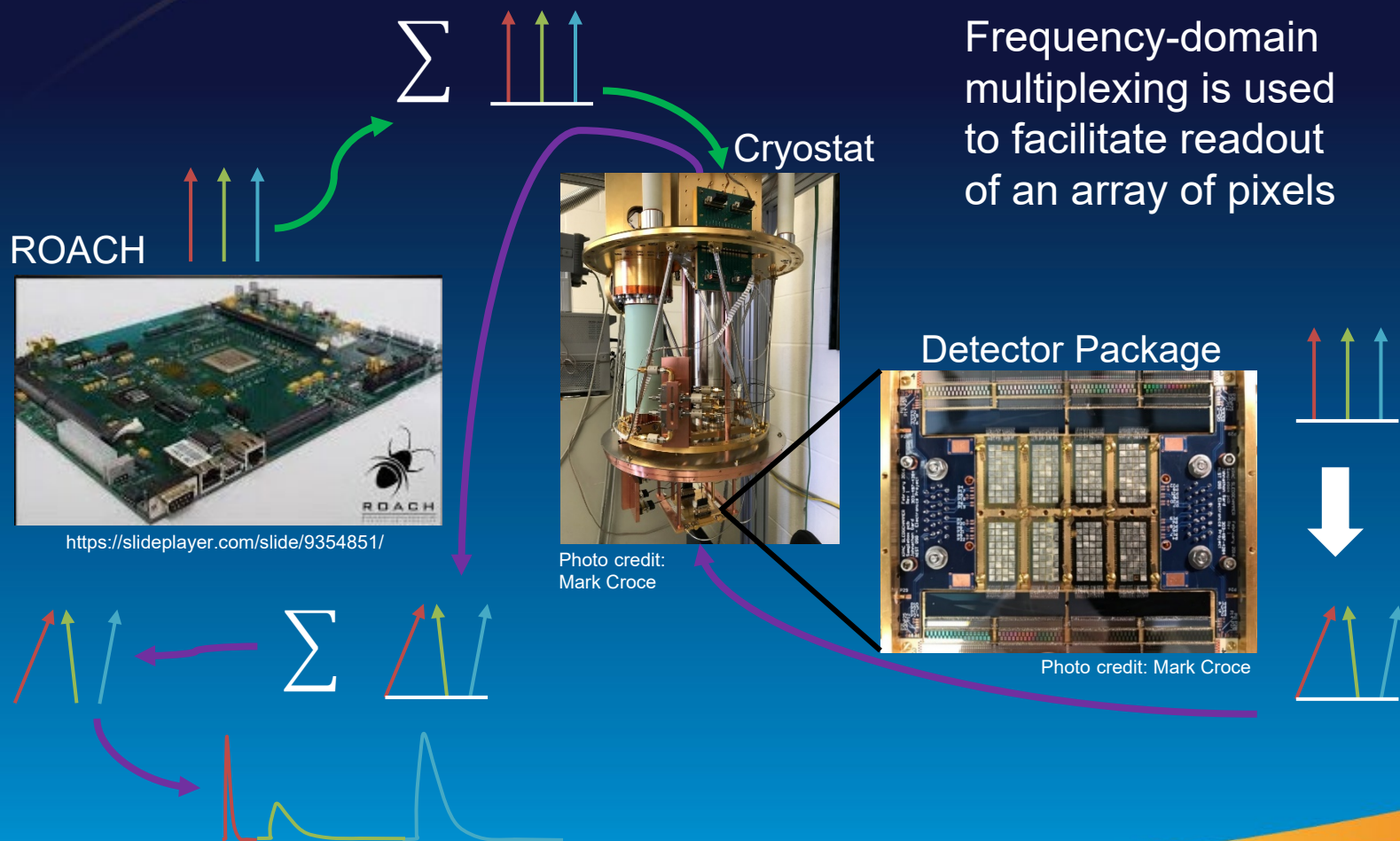
<https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-16-26714>



The height of each pulse is proportional to the energy of the photon

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A Bit More Complicated



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The Physical Instrument

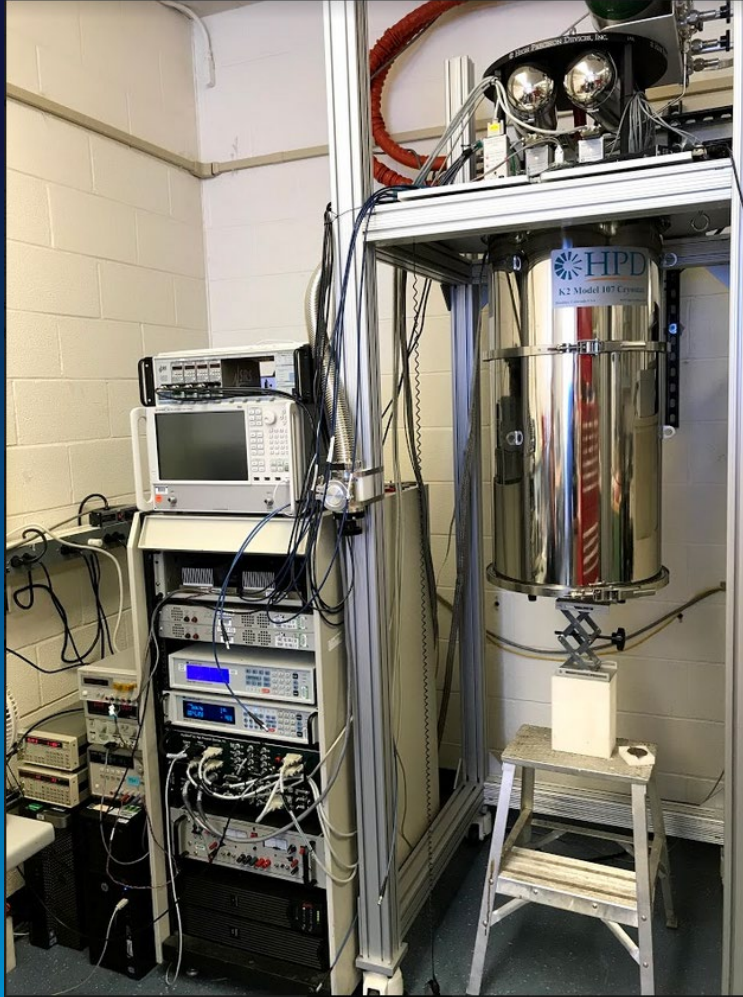


Photo credit: Mark Croce

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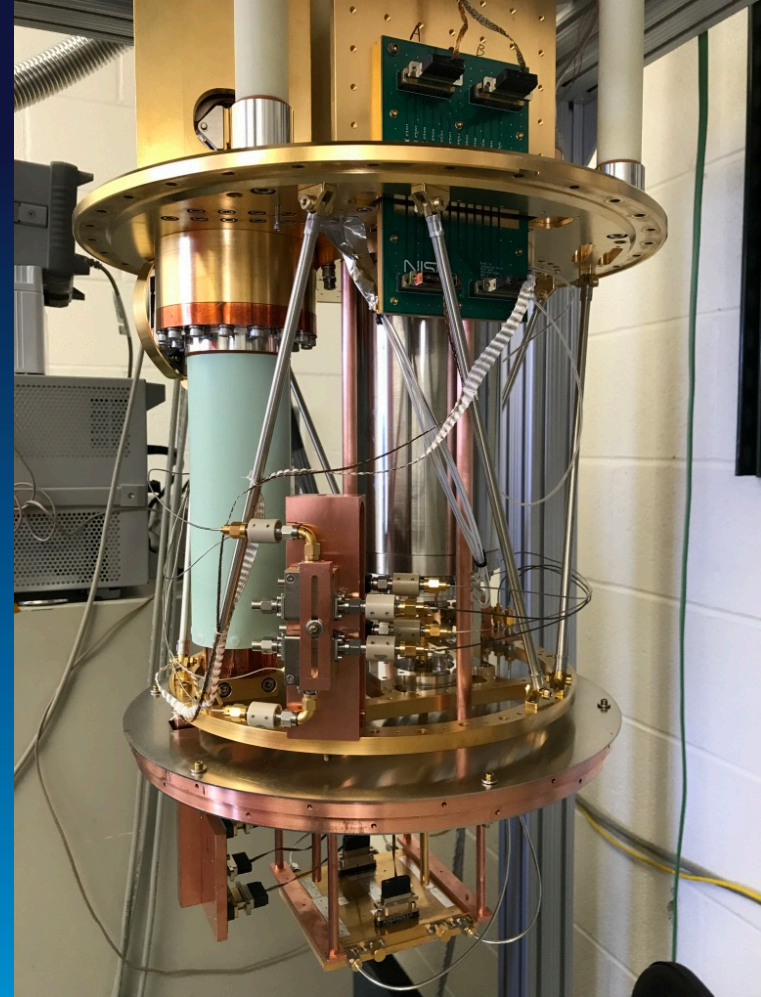


Photo credit: Mark Croce

Microcalorimeter User Manual

Shannon Kossmann, Katrina Koehler, and Mark Croce

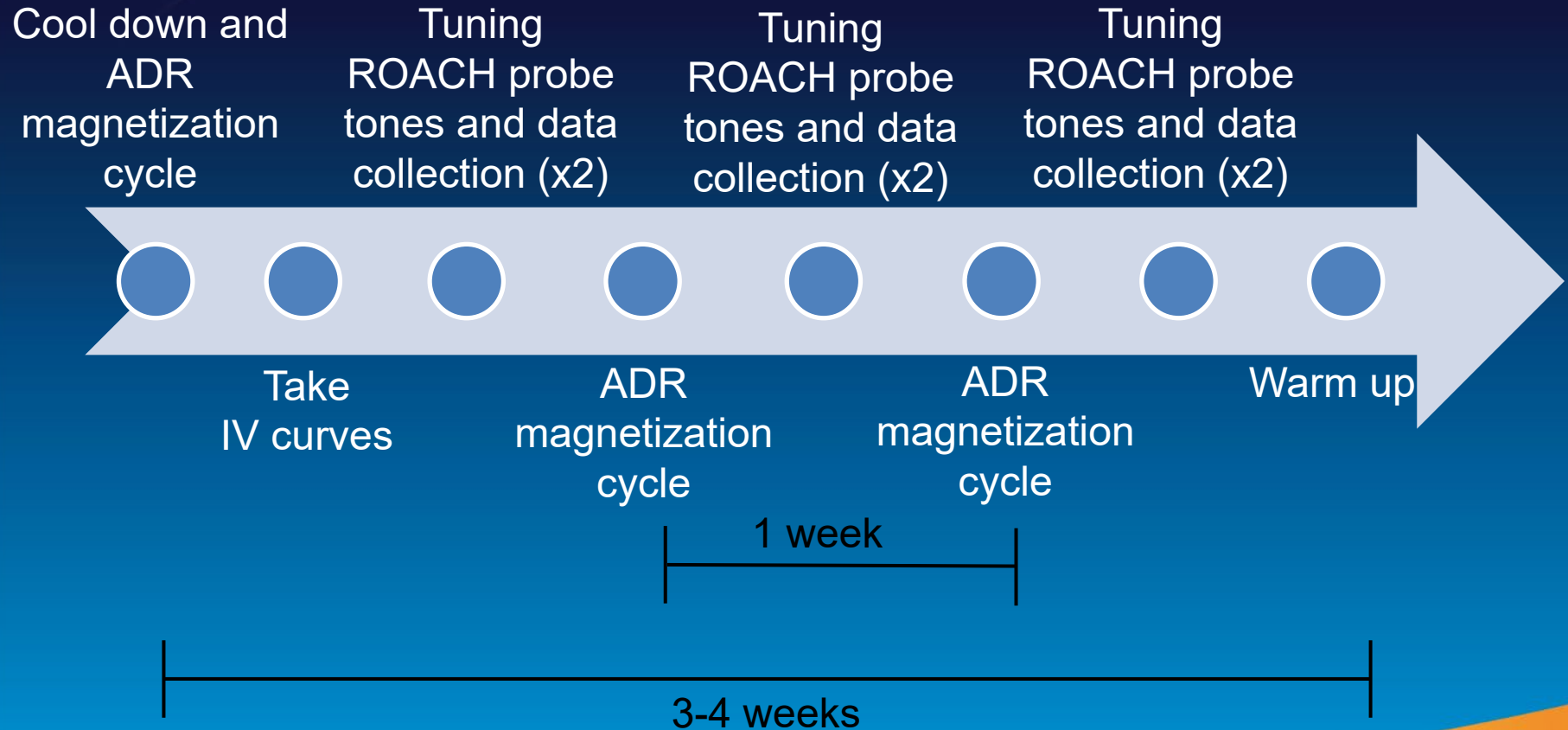
March 5, 2019

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Timeline



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Timeline

Cool down and
ADR
magnetization
cycle

Tuning
ROACH probe
tones and data
collection (x2)

Tuning
ROACH probe
tones and data
collection (x2)

Tuning
ROACH probe
tones and data
collection (x2)



Take
IV curves

ADR
magnetization
cycle

ADR
magnetization
cycle

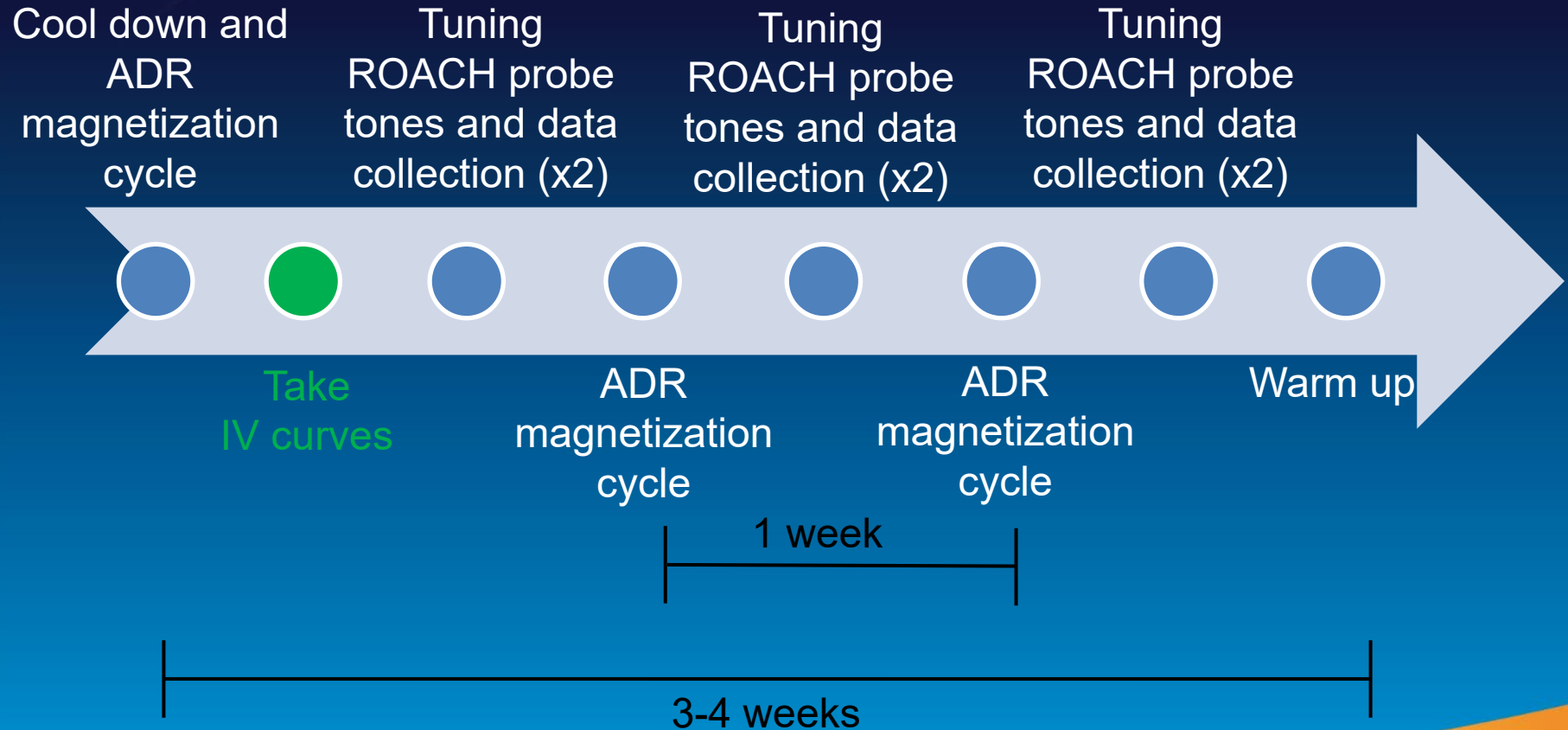
Warm up

1 week

3-4 weeks

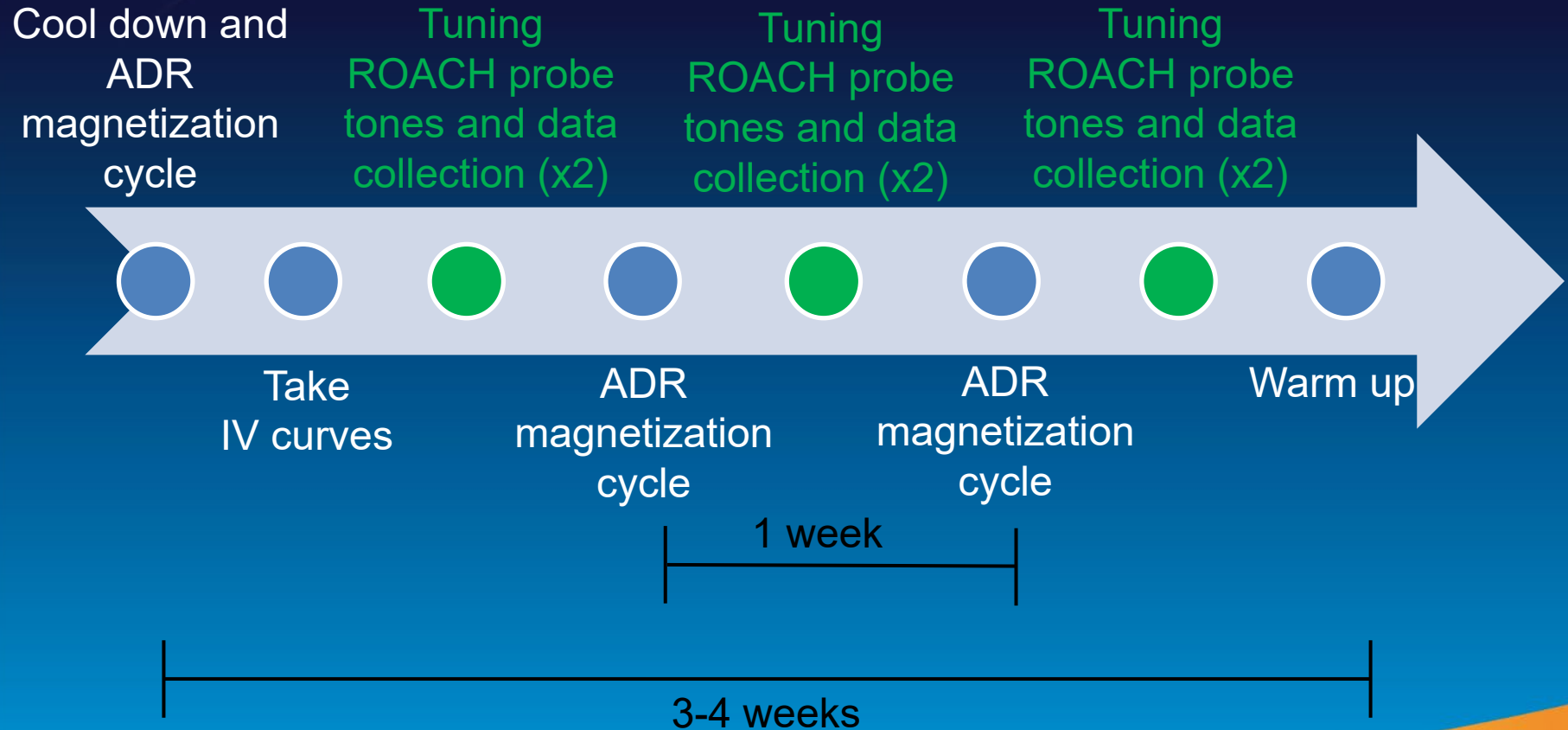
UNCLASSIFIED

Timeline



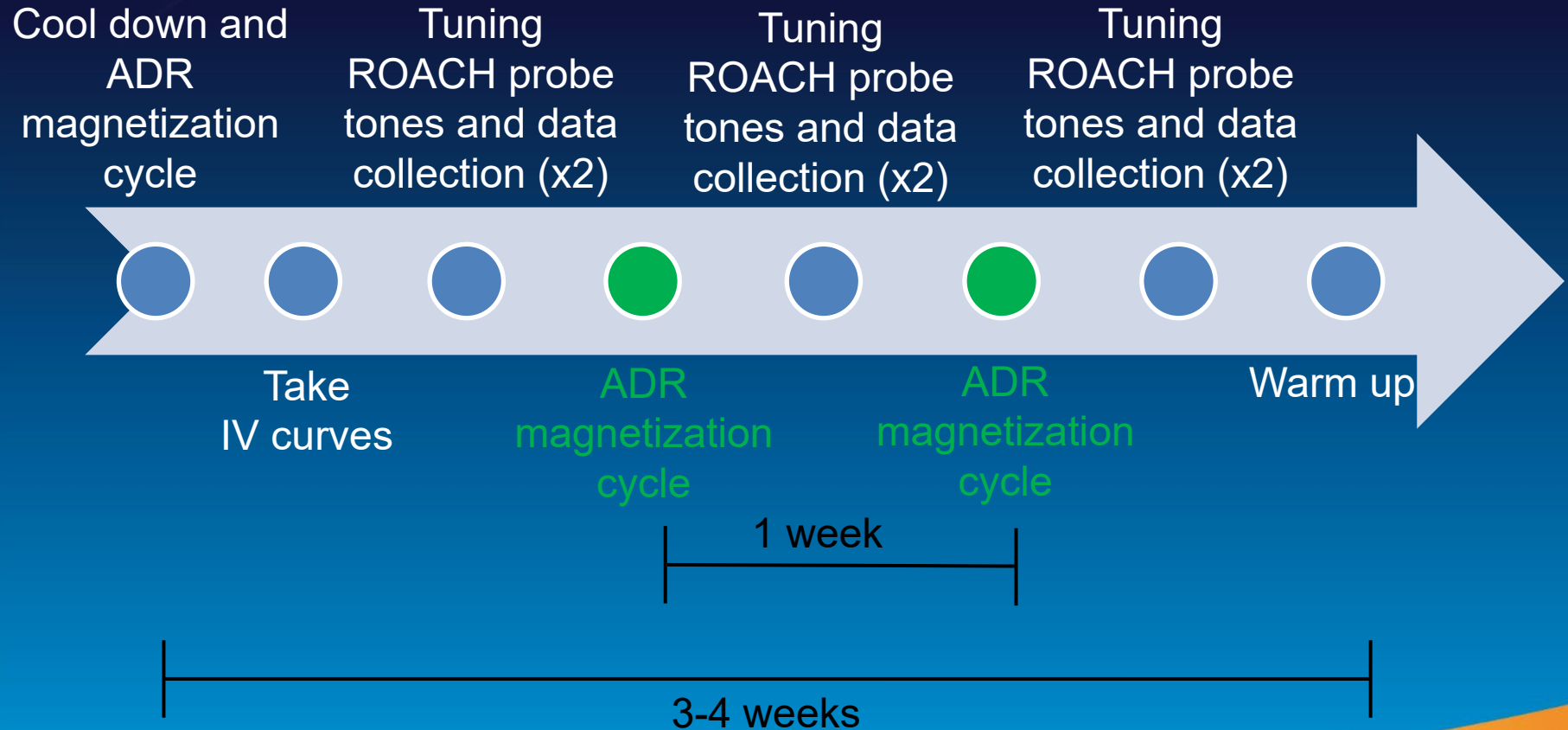
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Timeline



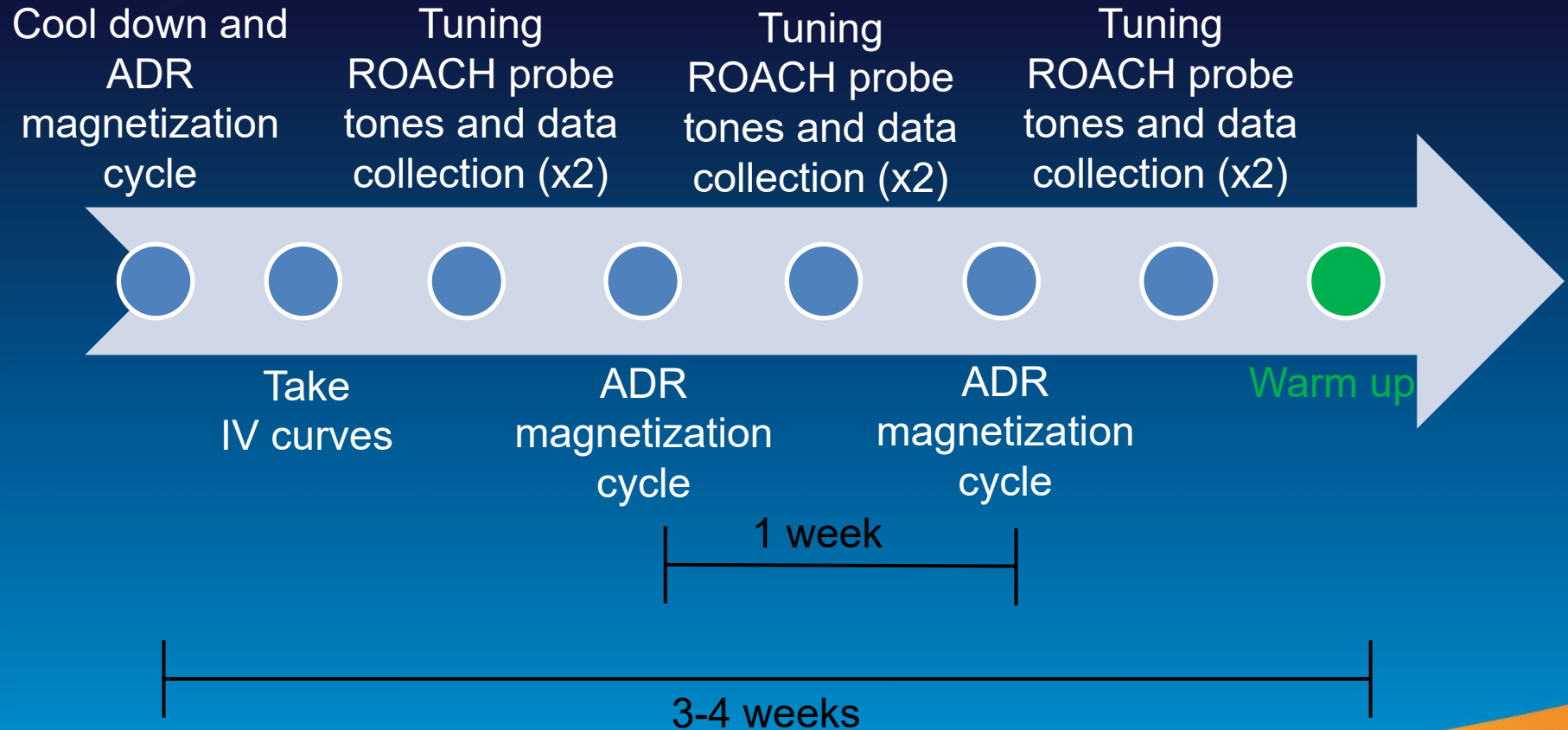
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Timeline



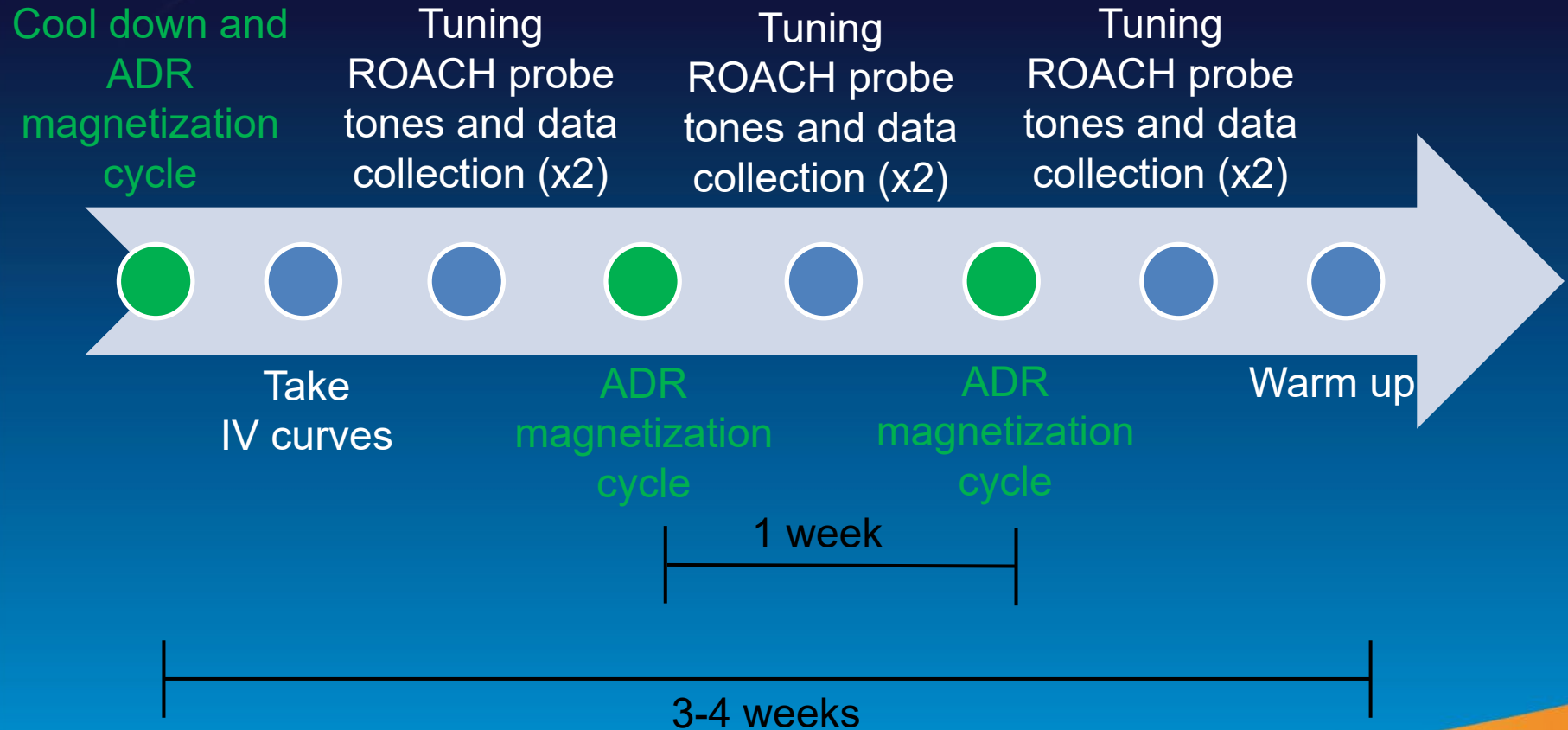
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Timeline



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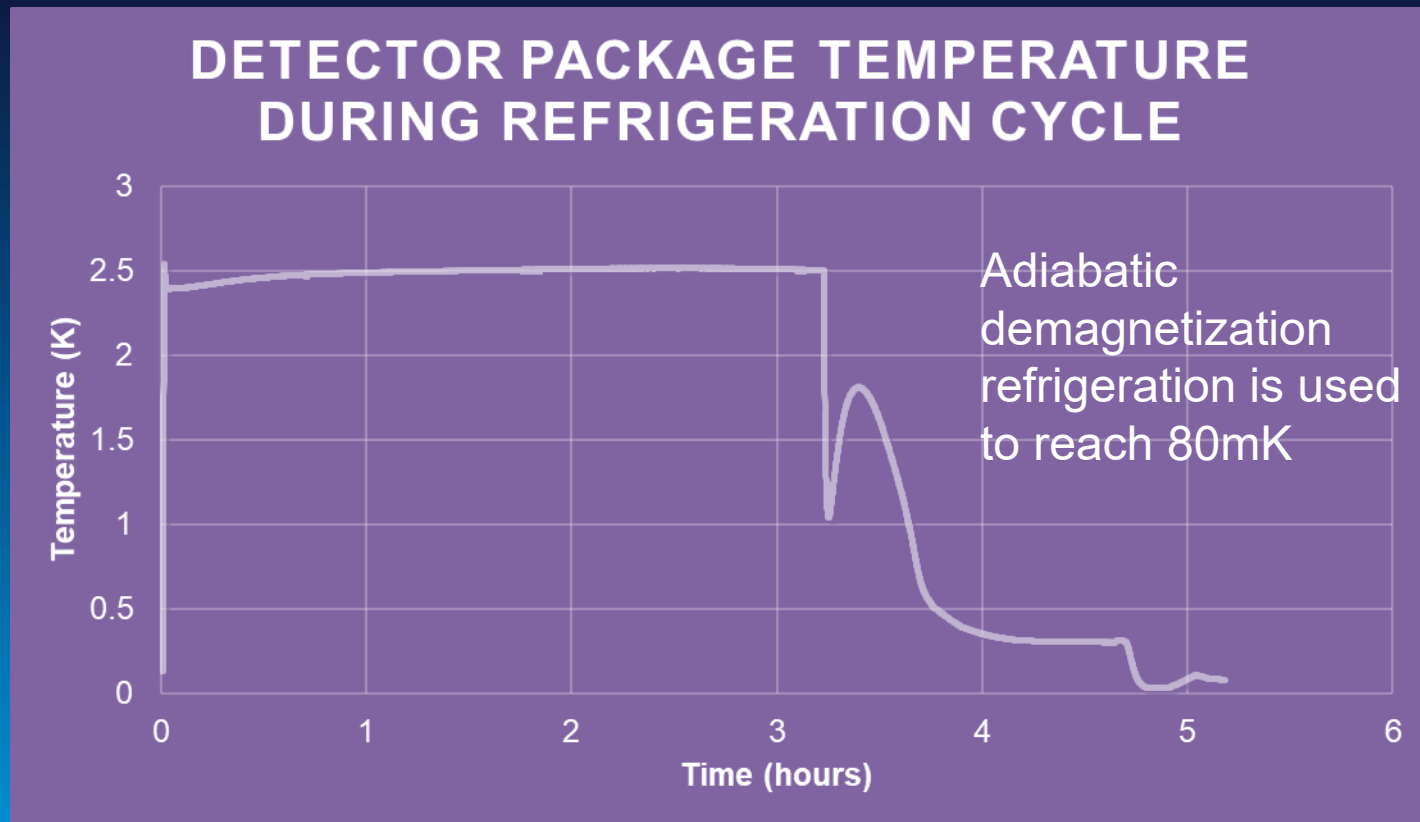
Timeline



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Running the Instrument

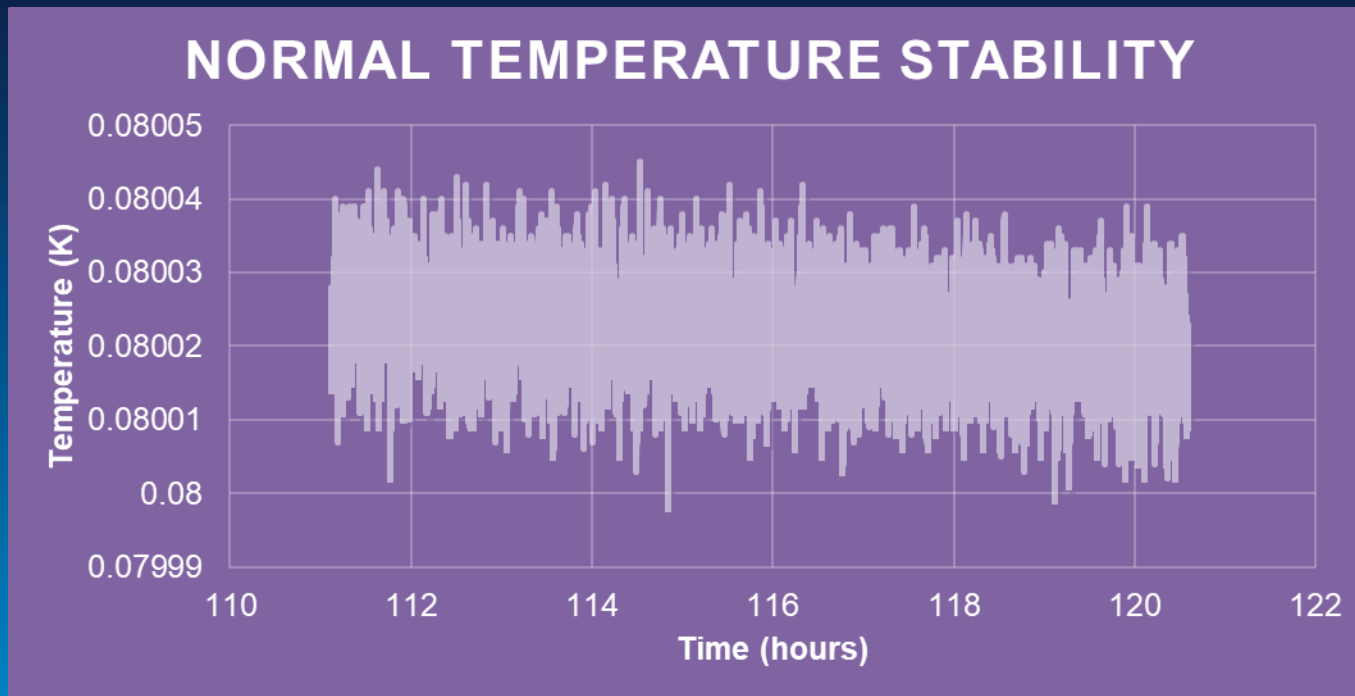
- Operating temperature (80mK)



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Running the Instrument

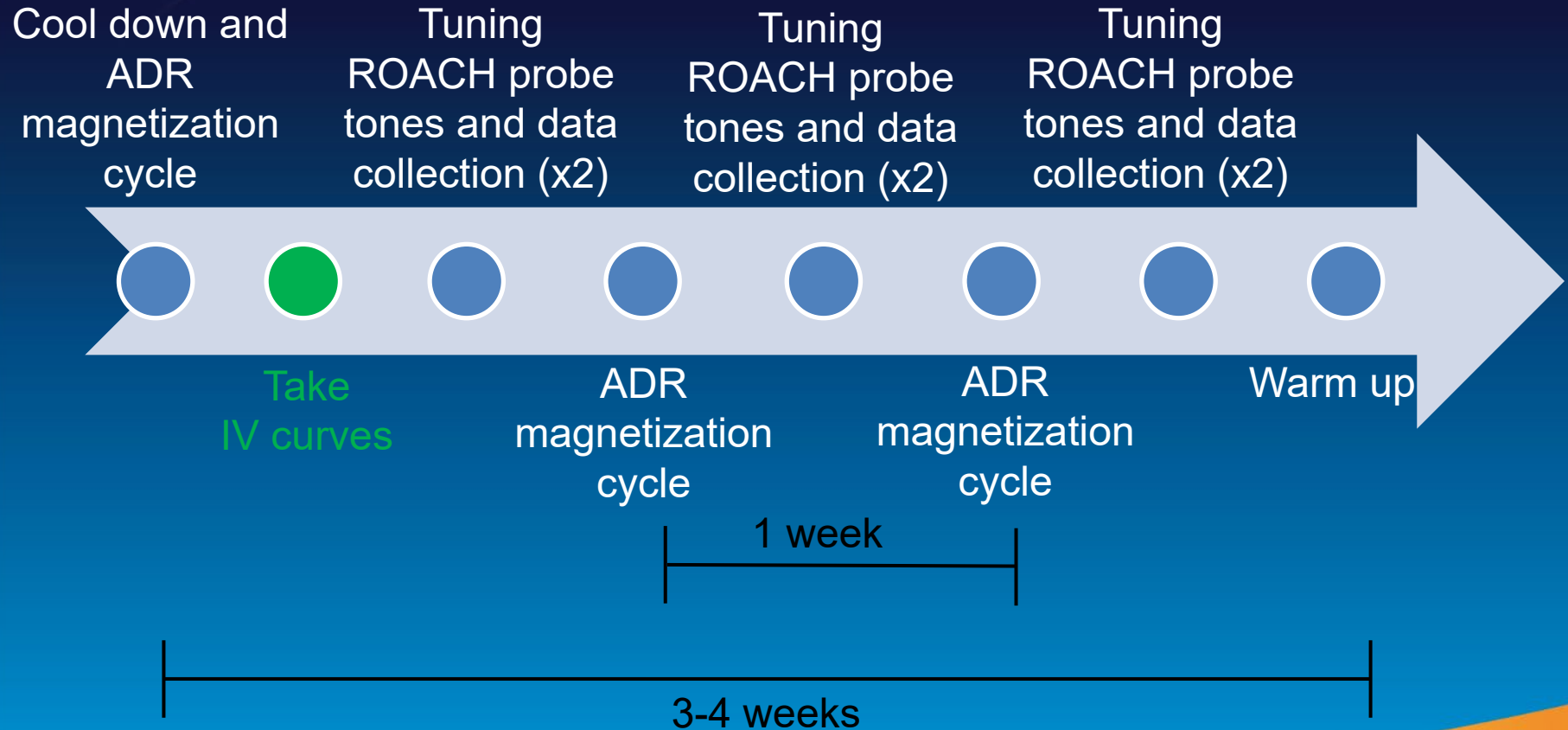
- Temperature/vibrational stability



Temperature and vibrational stability remain a challenge because of microcalorimeter sensitivity

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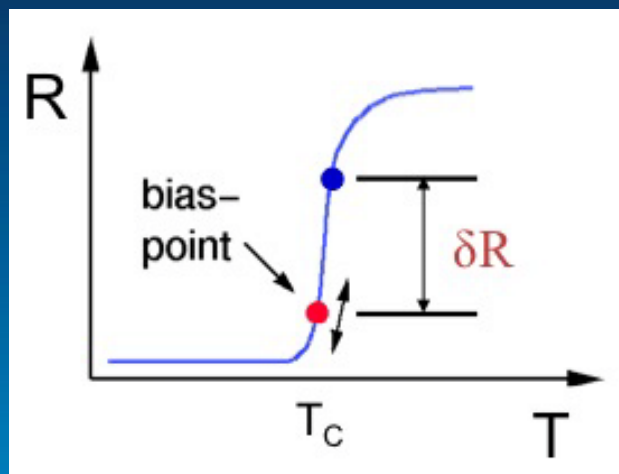
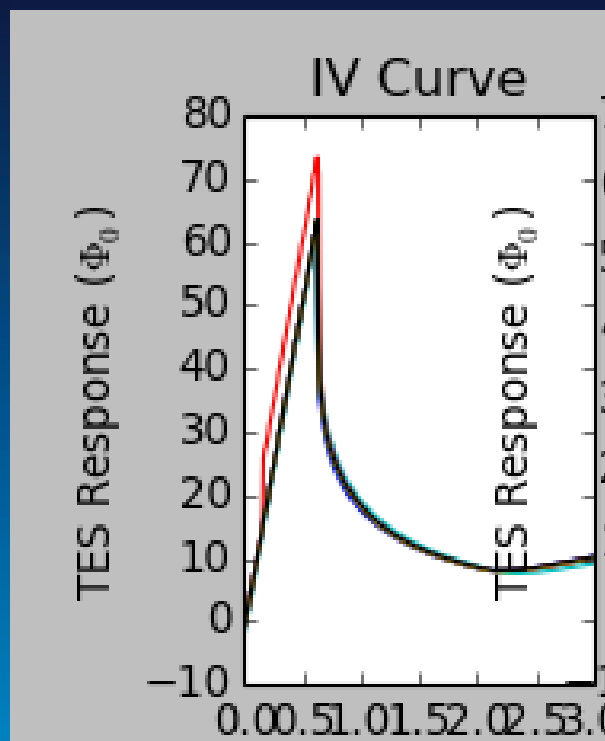
Timeline



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Running the Instrument

- Determining the TES bias value



https://www.researchgate.net/figure/Illustrative-plot-of-resistance-vs-temperature-for-a-superconductor-The-transition-is_fig4_228440334

The bias point is chosen low on the superconducting-normal transition edge

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Timeline

Cool down and
ADR
magnetization
cycle

Tuning
ROACH probe
tones and data
collection (x2)

Tuning
ROACH probe
tones and data
collection (x2)

Tuning
ROACH probe
tones and data
collection (x2)



Take
IV curves

ADR
magnetization
cycle

ADR
magnetization
cycle

Warm up

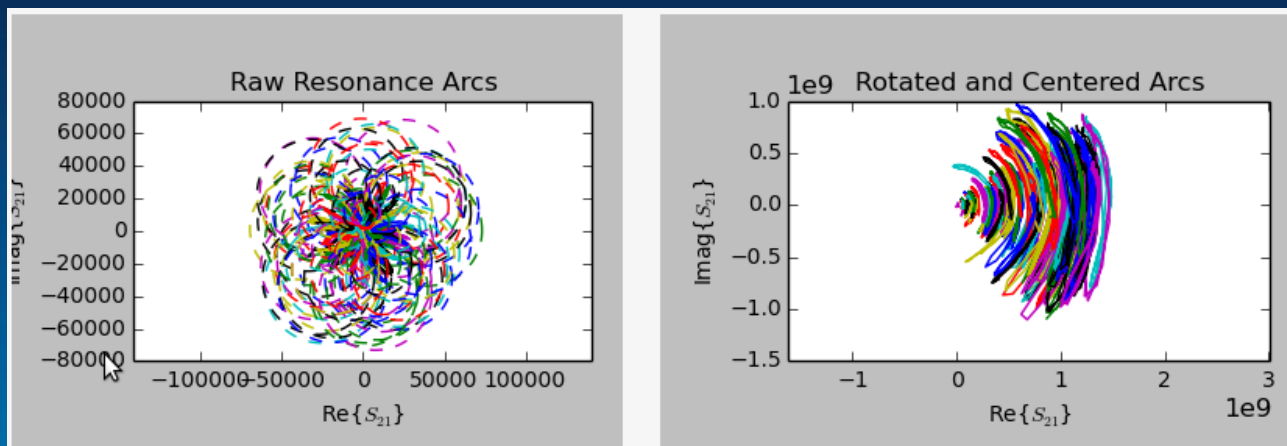
1 week

3-4 weeks

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Running the Instrument

- Checking ROACH generated probe tones

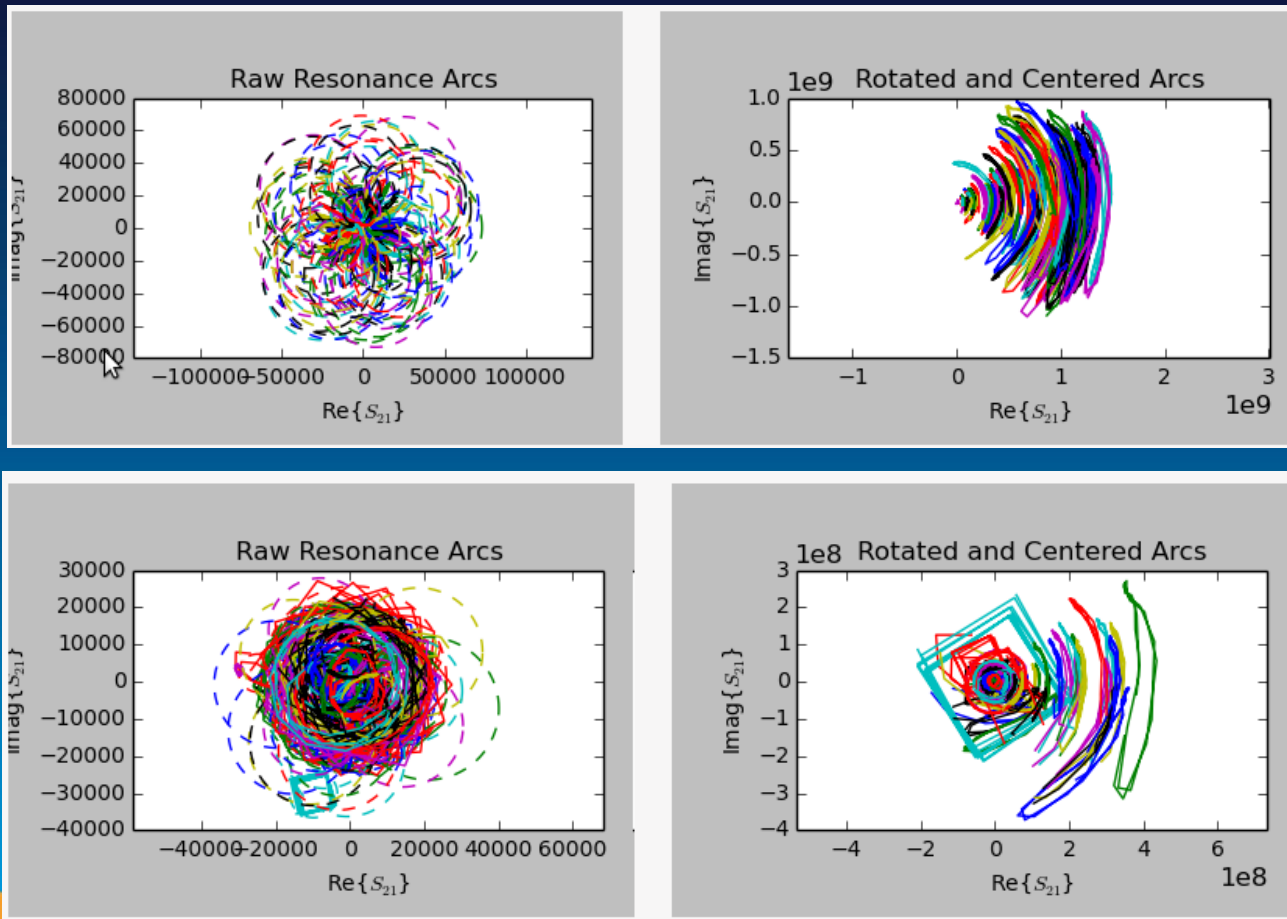


Each arc represents one pixel

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Running the Instrument

- Checking ROACH generated probe tones



Running the Instrument

Matter version 1.1.2
File Array Geom About

Data Acquisition GUI

Connection to data server

Server: localhost Port: 2001
Disconnect from server.
12.2 MB/s

Array Map Row/col Grid

Up to ~20 counts per pixel per second is ideal for measurement

Array total rate (pulses per second) 293
Color scale
Integ time 3.00 Max trig rate 50.0
New plot window Close all plots

Streams Triggers Writing Server Ctrl Group Trig Analysis Ch Names

Output file directory
/media/ucal/Drive3/190124

LJH Files File name generated from: Date_time
Output file name
/media/ucal/Drive3/190124/20190128_134613.ljh
*.ljh suffix Edit LJH header

Pulses to write 0 Stop writing; close file
Pulses recorded 207,795 Pause writing
0%

Single chan select

Channel	Count
Chan 3	2,688
Chan 193	2,806
Chan 35	2,136
Chan 97	0

What to write to files

- ☒ Write FB Channels
- ☐ Write Error Channels
- ☐ Write Auto Triggers
- ☐ Write Level Triggers
- ☒ Write Edge Triggers
- ☐ Write Noise Triggers

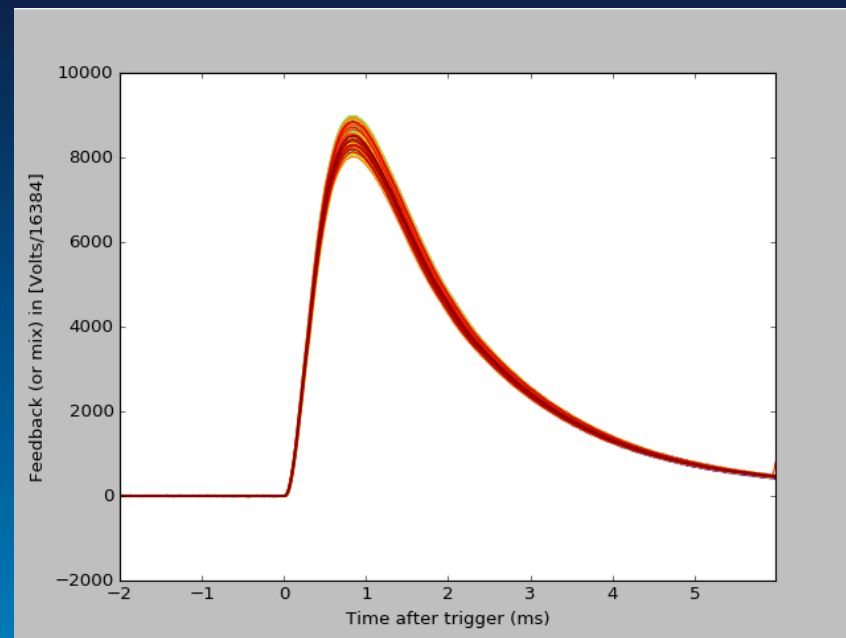
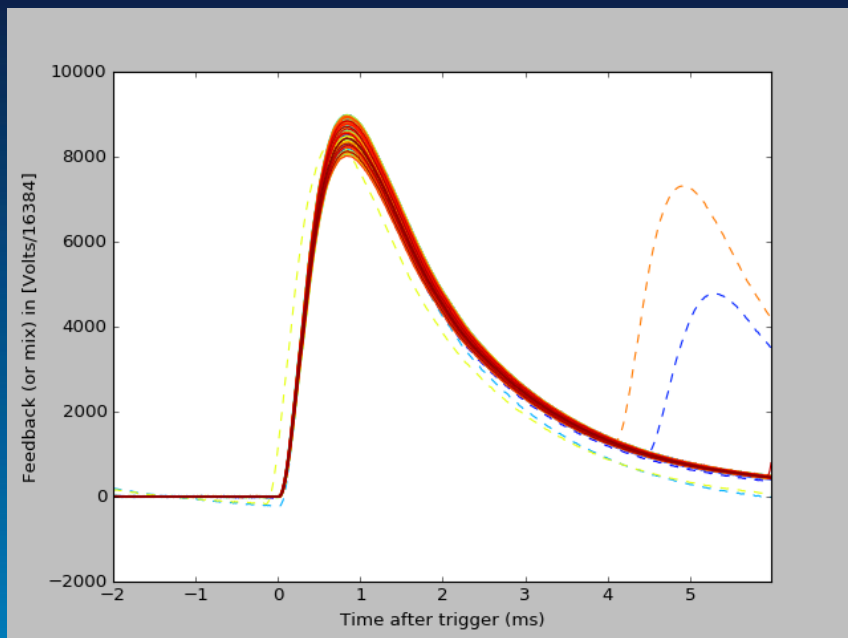
What goes here is a list of key analyzed info (eventually, expected energy resolution!)

Thu Jan 24 2019 16:20:11 Closed file 20190124_161957.noi for writing.
Thu Jan 24 2019 16:23:30 Opened file /media/ucal/Drive3/190124/20190124_162330.ljh for writing.
Mon Jan 28 2019 09:08:52 Closed file 20190124_162330.ljh for writing.
Mon Jan 28 2019 13:46:13 Opened file /media/ucal/Drive3/190124/20190128_134613.ljh for writing.

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Making a Spectrum

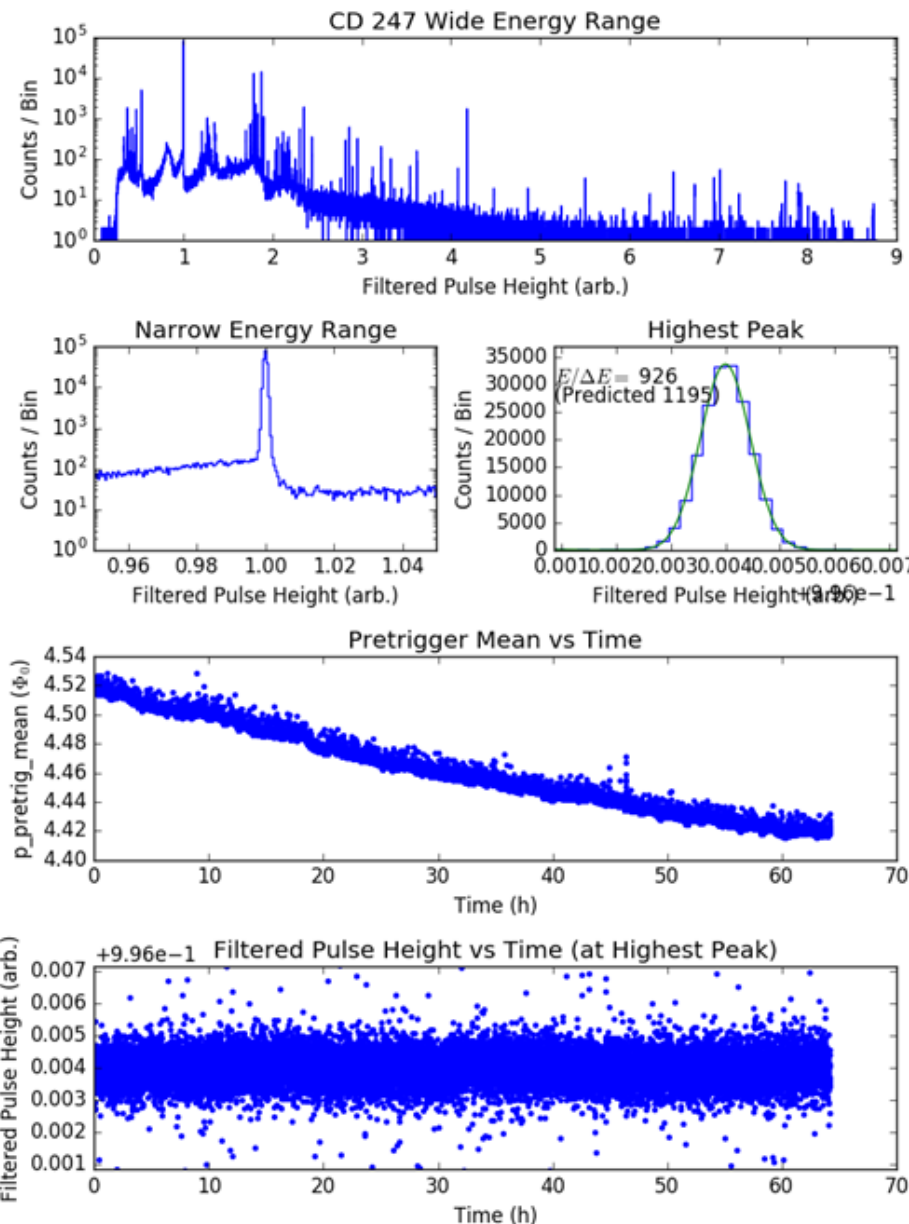
- Data saved! Now what?



Cut bad pulses and bad channels

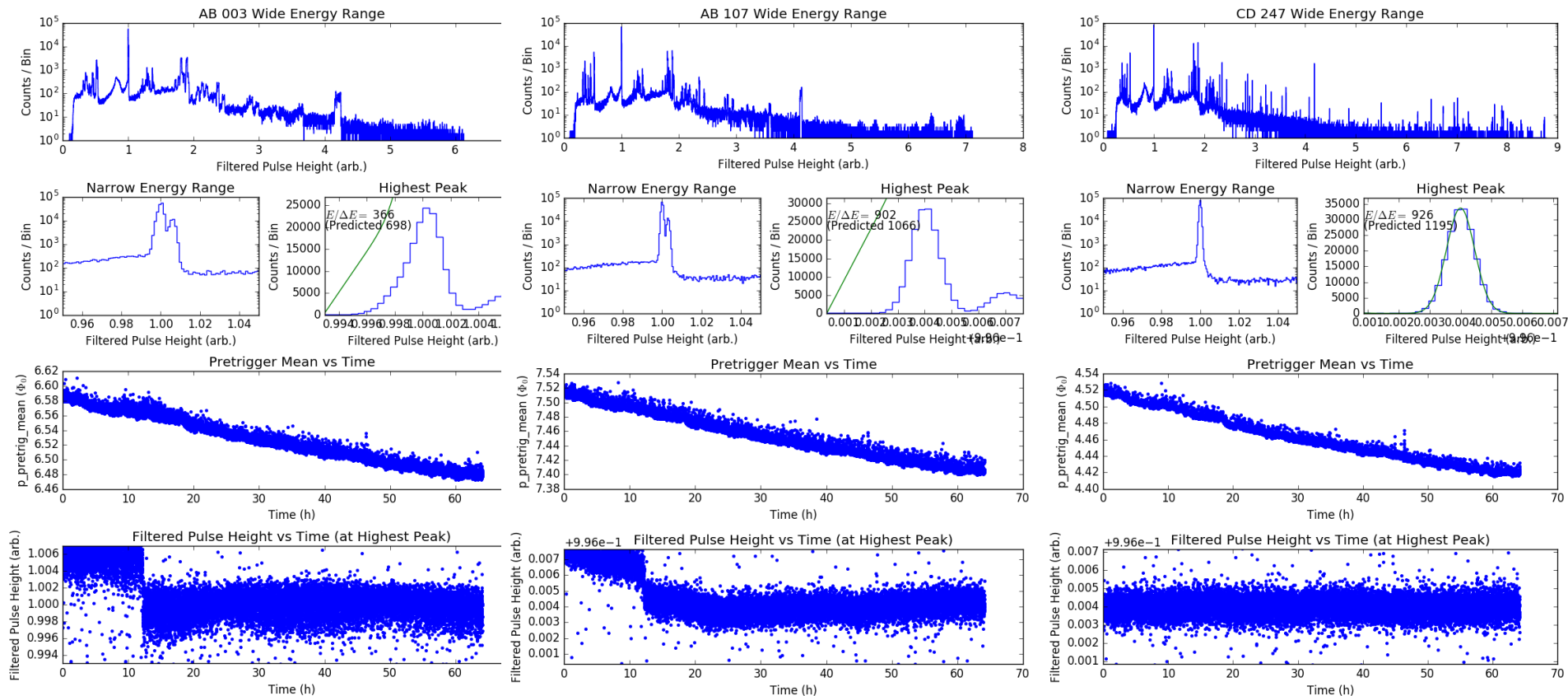
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Information is
compiled for each
pixel individually



Making a Spectrum

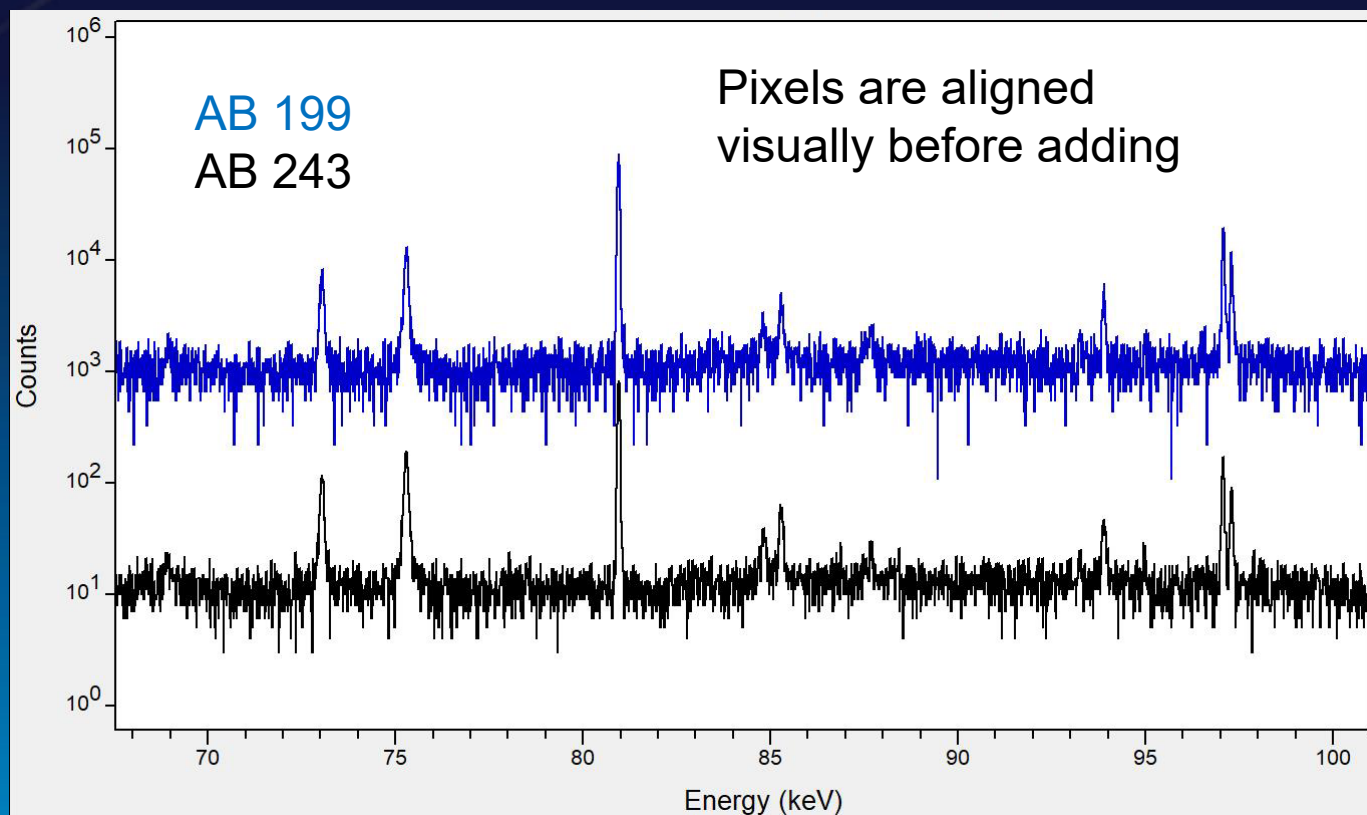
Every pixel is different



Eliminate double peaks

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Making a Spectrum



Co-57 + Ho-166m

Spectra from Mike Yoho

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Making a Spectrum

Low-burnup plutonium (PIDIE 6-1)

Parameter at 129.294 keV	Average	Co-added
FWHM [keV]	0.070	0.069
FWTM [keV]	0.13	0.14

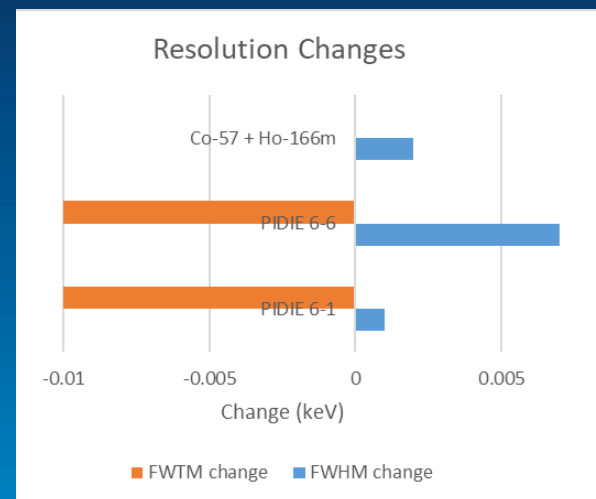
Energy resolution is
not degraded by
adding pixels

High-burnup plutonium (PIDIE 6-6)

Parameter at 129.294 keV	Average	Co-added
FWHM [keV]	0.096	0.089
FWTM [keV]	0.19	0.20

Co-57 + Ho-166m

Parameter at 80.57 keV	Average	Co-added
FWHM [keV]	0.068	0.066
FWTM [keV]	0.13	0.13



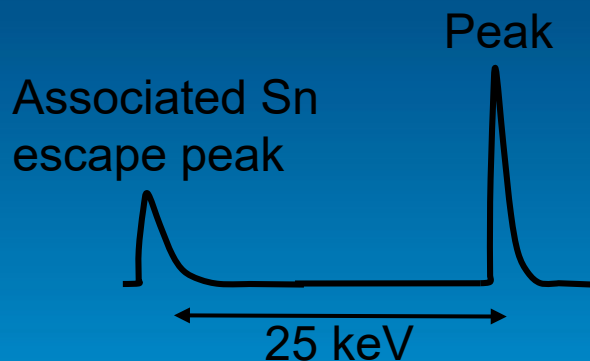
Data provided by Mike Yoho

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Making a Spectrum

- Energy Calibration

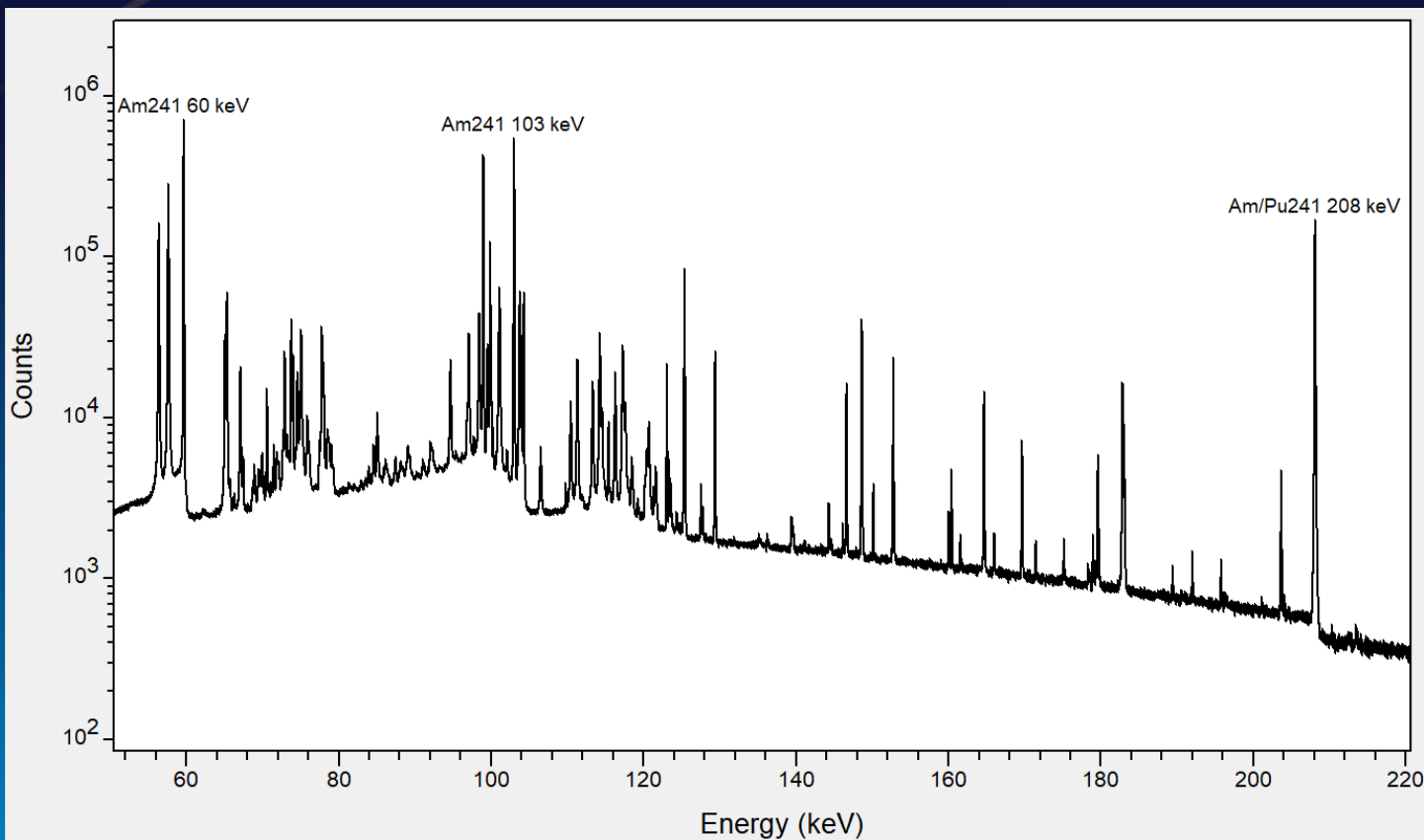
Peaks from Ta and Sn
to energy calibrate
spectrum without
knowing source



<https://www.vectorstock.com/royalty-free-vector/periodic-table-element-tantalum-icon-vector-20585357>

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Making a Spectrum



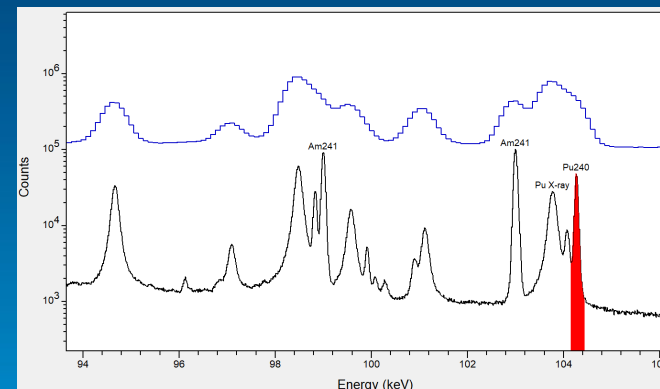
Spectrum from Mike Yoho

High-burnup plutonium,
~26% ^{240}Pu (CBNM 61)

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Conclusion

- Energy of absorbed particles recorded as pulses
- Frequency-domain multiplexing for readout of pixel array
- Good pulses used to create histogram
- Co-add pixels
- Energy calibrate
- Best spectra
- INL and field test



Low-burnup
plutonium,
~6% ^{240}Pu
(PIDIE 6-1)

Spectrum from Mike Yoho

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